Dynamics of soil nutrients in larch plantations[1]

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Abstract The annual dynamic changes of soil nutrients were measured in pure larch plantation and in mixed larch plantation in the arboretum of Inner Mongolia Academy of Forestry Science, Huhehaote. The results showed that soil nutrients in pure larch plantations changed rapidly in July and August. The variation of soil nutrients is more stable in mixed larch plantation. Compared with the pure larch plantation, the content of soil nutrients in mixed larch plantation obviously increased. The soil degradation occurred in the pure larch plantation, and related to the forest age.
Key words: Larch plantation, Dynamic of soil nutrients, Soil degradation

Introduction

The soil degradation of artificial forest is the core of research for plantation to stability and afforestation in China. In recent years, studies on soil fertility of plantations have gradually increased for Chinese fir, masson pine, poplar, larch, etc. Many specific measures have been put forward to maintain the soil fertility level in artificial forest (Pan 1997; Yan 1997; Yan 1996). Owing to variability of soil fertility in plantation, it has many difficulties to study the soil fertility. For example, the soil sample plot has to be moved horizontally in order to study the soil nutrient changes in different forests. We studied the dynamic changes of soil nutrients in larch plantations in the arboretum of Inner Mongolia Academy of Forestry Science. The results showed that the soil degradation in pure larch plantation actually existed.

Study site

The research site is located in the arboretum of Inner Mongolia Academy of Forestry Science. Geographical location is 40° 41' N, 111°41' E, with an elevation of 1 056 m. It belongs to temperate semi-arid region. The annual average temperature is 5.8℃. The annual highest temperature is 37.3℃, and annual lowest temperature is -32.8℃. The annual average rainfall is 417.5 mm. Annual average evaporation capacity and annual average relative humidity is 1784.6 mm and 42%~69% respectively. Frost-free period is 130d. The area is about 20 hm^2. The maximum of forest age is about 40a. Larch included *Larix decidua*, *Larix kaempferi*, *Larix olgensis*, *Larix sibirica* and *Larix principis-rupprechii*, etc.. *L. principis-rupprechii* was introduced in 1964, with the tree height of 15 m, and breast-height diameter of 26 cm. *L. olgensis* was introduced in 1976, with tree height of 12 m, and breast-height diameter of 16 cm.

Methods

The sample plots were in the pure larch plantation and mixed forest with scarce undergrowth. The thickness of forest litter was 2-3 cm. Canopy density was 0.9-1.0. Natural pruning was obvious. The other sample plot was *L. olgensis* pure plantation at the age of 22. Undergrowths were herbaceous plants. The thickness of forest litter was 0.5-1.0 cm. Canopy density was 0.6-0.7. Natural pruning was not clear. The soil sampling was made on the 15th in each month from May to September. Sampling depth was 0-20 cm and 20-40 cm. The control sample was uncultivated land that was 15 m away from forest edge. Soil nutrients were measured by conventional methods after air-drying in the room.

Results and analysis

The annual dynamic changes of soil nutrients in pure larch plantation

The dynamic changes of soil nutrients are closely related to tree growth, leaching and soil humus. The soil nutrients are more consumed during the vigorous period of tree growing and available nutrients are

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used up. The vigorous period of tree growth is also vigorous period of the soil biochemical action and microorganism activity in north region of China. It makes the change of soil nutrients more complicated. From Table 1, the annual variation of soil total P was kept in the range of 0.09%~0.1% in the 34-year-old pure larch plantation. And the contents of soil soluble P, soluble N and humus changed greatly, especially in the 0-20 cm soil layer. The change of soluble P is the largest from July to August. The soil total N had a tendency of continuously increasing from May to August, and sharply dropped in September. The soil soluble N content dropped to the lowest value in July, afterwards gradually increased and kept in the level above 1.5 $\mu g.g^{-1}$. The results showed that the fluctuation of soil nutrients was significant in July and August, when it was just rain season and high-temperature weather, and exchange of the energy and matter was in the strong progressing in the soil.

From Table 2, soil soluble N content dropped to the lowest valve in July in the 22-year-old pure larch plantation, total N content rose up to the highest valve in August. The soil soluble P content rose up to the highest valve in July. After August the soluble P content continuously decreased. The total P basically was in 0.08%~0.1%. The soil humus content change was more complicated. The change of the soil pH value was significant. The highest value of soil pH was 8.52-8.72 in August.

Although for the ages of the two larch plantations are different, the annual change tendency of soil nutrient content basically keeps identical. It is obvious that the change period of soil nutrients in larch plantation is from July to August. In this period the soil soluble N content dropped to the lowest, but the soil soluble P content rose up to the highest. The total N content kept at a high level.

Table 1. Variation of soil nutrients in pure larch plantation

Month	Age/a	Soil layer /cm	Total P %	Soluble P /μg·g^{-1}	Total N %	Soluble N /μg·g^{-1}	Humus %	pH
May	34	0 - 20	0.098	5.35	0.0418	0.47	1.15	8.48
		20 - 40	0.090	3.35	0.0345	1.47	1.21	8.30
June		0 - 20	0.100	5.35	0.0539	0.28	1.87	8.30
		20 - 40	0.090	4.40	0.0396	1.47	1.60	8.44
July		0 - 20	0.100	8.85	0.0489	0.16	--	8.38
		20 - 40	0.100	4.85	0.0486	1.16	1.66	8.52
August		0 - 20	0.096	7.00	0.0625	0.59	1.74	8.52
		20 - 40	0.097	4.60	0.0476	1.47	0.95	8.52
September		0 - 20	0.095	6.10	0.0340	0.59	0.96	8.50
		20 - 40	0.093	4.30	0.0380	1.77	0.96	8.46

Table 2. Variation of soil nutrients in pure plantation

Month	Age /a	Soil layer /cm	Total P %	Soluble P /μg·g^{-1}	Total N %	Soluble N /μg·g^{-1}	Humus %	pH
May	22	0–20	0.106	16.25	0.047	1.77	4.10	8.38
		20 - 40	0.102	14.85	0.058	0.86	2.97	8.52
June		0–20	–	–	–	–	–	–
		20 - 40	0.109	15.65	0.063	1.47	3.07	8.48
July		0 - 20	0.108	18.50	0.059	1.04	4.22	8.36
		20 - 40	0.086	7.30	0.046	1.16	3.70	8.36
August		0 - 20	0.080	10.35	0.079	1.16	1.10	8.52
		20 - 40	0.090	10.75	0.060	1.47	1.87	8.74
September		0 - 20	0.088	13.85	0.082	1.22	2.94	8.36
		20 - 40	0.068	11.75	0.043	1.16	1.66	8.56

The dynamic change of soil nutrients in the mixed larch plantation

The forest floor in the mixed forest was obviously different from that of the pure larch plantation, as the mixed forest included the part of the broadleaf trees. According to the study (Yan 1993) in the mixed broad-leaved and coniferous forest, not only the broadleaf litter quickly decomposes, but also the decomposition of coniferous litter was promoted. The physical and chemical properties of soil are improved. From Table 3, the soil total P basically maintained at the range of 0.09%~0.1% in the mixed forest, soluble P began to display decreasing tendency in June, and soil total N basically stabilized at the level of above 0.05%, except the two lowest values in July and

September. The soil soluble N basically showed the decreasing tendency and decreased to the lowest value in August. Compared with the pure larch plantation, the soil humus content in the mixed forest kept a higher level (above 3.7%). The soil pH value basically maintains in the range of 8.3-8.4. The annual change tendency of soil nutrients in the mixed forest is unanimous with 34-year-old pure larch plantation. This shows that there aren't obvious effects on the annual dynamic change of soil nutrients to compare with that of the mixed broad-leaved and coniferous forest. But compared with the pure larch, the changes of nutrients in mixed forest are more complicated. The range of change is more stable.

The variation of annual average value soil nutrients in different plantations

The changes of annual average value of soil nutrient can reflect the tendency of rise and declining of soil nutrient content. Many researches showed (Pan 1997) that afforestation of pure larch plantation could easily lead to degradation of soil fertility. It was difficult to reflect the annual change of soil nutrients, as the measured result was random measuring value at a certain day. From Table 4, the pure larch plantation can easily lead to the soil fertility degradation with the increase of the forest age; the tendency of soil fertility degradation is intensive. This result showed that the fact of soil fertility degradation existed in the pure larch plantation in north district of China.

Table 3. Variation of soil nutrients in artificial mixed larch forest

Month	Age /a	Soil layer /cm	Total P %	Soluble P /μg·g^{-1}	Total N %	Soluble N /μg·g^{-1}	Humus %	pH
May	34	0 - 20	0.099	17.70	0.055	2.69	3.85	8.32
		20 - 40	0.091	5.05	0.032	0.86	0.64	8.48
June		0 - 20	0.098	18.90	0.056	1.89	3.77	8.36
		20 - 40	0.098	12.35	0.046	1.47	3.32	8.56
July		0 - 20	0.100	15.00	0.046	1.47	3.33	8.52
		20 - 40	0.088	6.25	0.038	2.08	2.71	8.34
August		0 - 20	0.099	10.30	0.054	1.16	4.09	8.42
		20 - 40	0.092	8.00	0.048	0.31	3.38	8.30
September		0 - 20	0.097	12.60	0.029	1.47	3.75	8.42
		20 - 40	0.095	8.10	0.039	1.47	3.63	8.80

Compared with the control sample, in the soil layer of 0-20 cm, contents of soil soluble P, total N, soluble N and soil humus decrease to 43.32%, 18.64%, 11.44% and 42.34%, respectively in the 34-year- old pure larch plantation. In the 20-40 cm soil layer, the contents of soluble P, total N, soluble N and soil humus decrease to 39.09%, 10.64%, 10.45% and 7.43% respectively. The soil pH value (0-20 cm, 20-40 cm) decreases to 0.18 and 0.06 respectively. Compared with the control sample, all kinds of soil nutrients content in the 22-year-old pure larch plantation significantly increase except for the soil soluble N and soil pH value. This result shows that stand age is a factor affecting the soil degradation of the larch plantation.

Table 4. The annual average value variation of soil nutrients in larch plantations

Sample type	Age /a	Soil layer /cm	Total P %	Soluble P /μg·g^{-1}	Total N %	Soluble N /μg·g^{-1}	Humus %	pH
Pure larch	34	0 - 20	0.098	6.53	0.048	1.42	1.43	8.44
		20 - 40	0.094	4.30	0.042	1.47	1.27	8.45
Pure larch	22	0 - 20	0.096	14.73	0.067	1.30	3.09	8.41
		20 - 40	0.091	12.06	0.054	1.22	2.53	8.53
Mixed forest	34	0 - 20	0.097	14.96	0.048	1.73	3.76	8.41
		20 - 40	0.093	7.95	0.041	1.23	2.74	8.50
Control		0 - 20	0.096	11.52	0.059	1.60	2.48	8.62
		20 - 40	0.082	7.06	0.047	1.64	1.75	8.51

When the forest canopy closes, undergrowth disappears, coniferous litter increase, these factors influence the return capability of system nutrients, and lead to over-consume of soil nutrients and soil fertility degradation. From the change of the forest age, the contents of soil soluble P, total N, and soil humus in 34-year-old larch plantation significantly decreased, compared with the 22-year-old larch plantation. But

soil total P and soluble N contents in 34-year-old larch plantation were higher than the 22-year-old larch plantation. This result shows that the soil in 22-year-old larch plantations expresses the indication of soil fertility degradation. If the management is strengthened timely, undergrowth can be renewed and the soil fertility can be kept at fixed level. Otherwise, the soil fertility will be decreased and tree growth is inhibited. For the same age of the mixed broad-leaved and coniferous forest in 0-20 cm soil layer, the contents of soluble P, soluble N and humus are significantly higher than those of the pure larch plantation. Total P, total N and soil pH values are the same as that of the pure plantation. Soil soluble P, soluble N and humus contents increase by 55.67%~45.92%, 18.34% and 61.97%~53.65% respectively. Compared with the control sample, in 0-20 cm soil layer in the mixed forest, soil soluble P, soluble N and humus contents slightly increase. Soil pH value decreases to 0.2. Soil total P basically keeps unanimous, but the soil total N decreases a little. This result showed that afforestation of mixed forest could improve soil nutrients. Inter-media cuttings should be timely engaged in managing the larch plantations so as to promote growth of undergrowth and renew the soil fertility. Afforestation of mixed broad-leaved and coniferous forest can promote the decomposition of litter to accelerate the return of nutrients and keep fixed soil fertility level.

Conclusions

To sum up, the annual variation of soil nutrients is very complicated in pure larch plantation. Forest age and composition are the factors influencing the dynamic change of nutrients. In the growing period, the period of maximum change for soil nutrients content is in July and August. Soil soluble P and total N increase, soil soluble N obviously decreases. Soil total P basically maintains at stable level. Soil pH value decreases a little. The annual average value variation of soil nutrients can basically reflect the final results of rise or declining of soil nutrients. It can lead to the soil fertility degradation to afforest pure larch plantation in large area in north of China. But many researches showed (Pan 1997) that inter-media cuttings in time could promote the growth of undergrowth in managing the pure larch plantation; and afforestation of mixed forest could play an active role in keeping the soil fertility.

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